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A FIELD METHOD FOR MEASURING PATTERNS OF WATER DROPPED FROM HELICOPTERS

by

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ABSTRACT

Detailed instructions allow field units to determine the concentrations of water or retardant applied on a fireline.

KEYWORDS: Helicopters, aerial fire control.

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A quick and economical method for field use has been developed to measure ground distribution patterns of water and fire-retarding liquids dropped from aircraft. The method was used successfully at the Institute of Northern Forestry in studying water requirements for suppressing fine fuel fires.

The measurement capability was developed for helicopters using helibuckets to drop water. The system can be used for retardants, but the problem of cup contamination has to be recognized. The system can be used for fixed-wing aircraft, but there are possible problems with splash from the ground surface into the cups.

Collecting drop pattern information and interpreting the results demand judgment and forethought. Planning and analyzing the drop pattern measurement is the responsibility of the professional fire control officer. Clearly defining the purpose of the test, establishing criteria for acceptance or rejection, and considering alternative recommendations will be time well spent. This article concerns detailed procedures which allow field units to measure drop concentration patterns for current and new equipment.

This simple measurement system is limited by area coverage and sample size. Even for helicopters with helibuckets, the sampling grid is limited to the central portion of the pattern and the extreme edges are left undefined. Researchers are beginning to deal with the problem of setting criteria for system measurement accuracy and developing procedures to define resolution or sensitivity. The absolute accuracy or variability of this system has not been established.

Equipment

A set of specialized cupholders that can be easily built is required. One cupholder is required for each sampling point in a grid covering an area slightly larger than the estimated drop pattern. The cupholders are wooden receptacles constructed from 2x10 dimensional lumber cut to make 9½- by 9½-inch squares. Seventy of the wooden receptacles allowed the layout of a suitable sampling grid in this study. However, the size and shape of the grid can be adjusted to suit specific needs.

The concentration of water or retardant falling at each point in the array is sampled with open plastic cups. A certain amount of efficiency is built into the system by constructing the cupholders to accept more than one cup. Holders that accept nine cups give the system capability to make that many consecutive passes without stopping to replace cups. A sampling grid of 70 cupholders with nine cups each would require 630 cups with lids--4 ½-ounce plastic cups[1] serve satisfactorily.

The 9½- by 9½-inch wooden cupholder blanks should be drilled with nine equally spaced 2¼-inch-diameter holes into which the plastic cups can be inserted by twisting to a friction fit (fig. 1). Each block should be numbered so that its place within the grid can be identified. Each hole within the wooden receptacles should also be numbered so that it can be identified. A two-number system, i.e., 70-9, allows each cup to be associated with a block in the sampling array and a particular cup within the block. The cups should be numbered with permanent ink or an etching tool. This numbering scheme is useful for developing systematic procedures for laying out the array and, later on, in keeping track of the data. Another reason for etching the numbers on the cups is array reassembly in case a concentration of drop material should tip the receptacles and scatter the plastic cups.

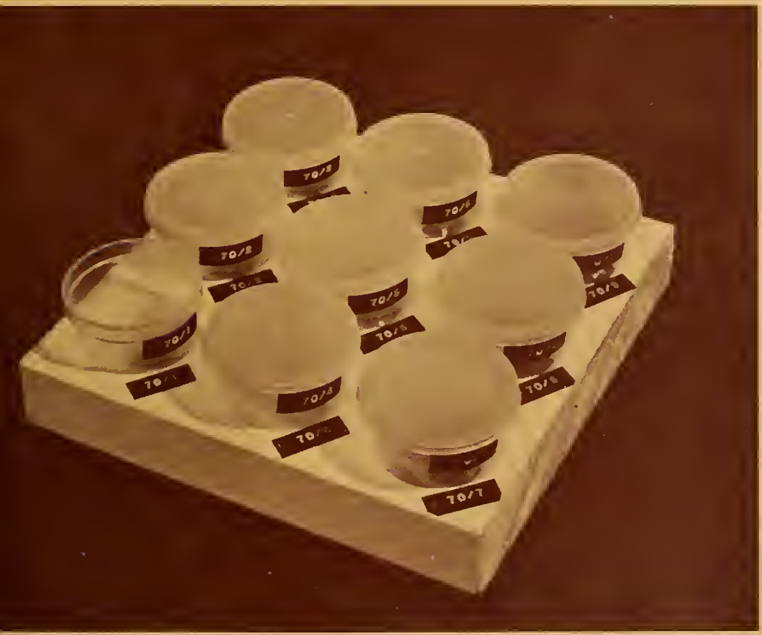

Figure 1.--*Wooden receptacles with nine friction-mounted plastic cups with tags that identify their location within the grid.*

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[1] The plastic containers with lids can be obtained from Falcon Plastics, Division of V-D Laboratories, Inc., 5500 West 83rd Street, Los Angeles, Calif. 90045. (The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U. S. Department of Agriculture of any product or service to the exclusion of others which may be suitable.)

Procedures

Preparation.--A simple form will facilitate recording information for each pass (fig. 2). The form should provide a place to record aircraft speed, altitude, windspeed, pass number, type of aircraft and gate settings if applicable, and information on any other factors that are being evaluated. The form should provide space to enter four values for each sample point in the array. Values recorded for each sample point are weight of the capped cup with water, tare weight of the capped cup, weight of the water, and concentration. The form layout should provide space for subtracting to obtain the weight of water and converting this value to a standard unit of measure, such as gallons per 100 square feet.

Most of the equipment needed to conduct the tests is available to a forestry-oriented fire control organization. Equipment required in preparation is:

1. Portable tape recorder (desirable)
2. Set of forms (one for each pass)
3. Belt weather kit
4. F. M. radio communication (two each, one in plane, one on ground)
5. Haga altimeter (or Abney level with a percent scale)
6. Approximately 70 wooden receptacles with 630 plastic cups and lids properly numbered for identification
7. 100-foot tape
8. Weighing scale (top loading type, accurate to 0.1 gm.).

The portable tape recorder records remarks and observations during the flight. The Abney level or Haga altimeter measures aircraft height. Lack of an accurate weighing scale is not a problem, as the cups can be transported to an available scale.

Plot layout.--A 100-foot tape and the simplest of survey techniques are appropriate for laying out the sample grid (fig. 3). A hard surface such as a runway taxi strip is a preferred location to set up. A hard surface does not get muddy after repeated drops and makes it easier to work. Some retardants cannot be dropped on a hard surface if they are corrosive. A 7 by 10 array with 5 feet between columns (parallel to the line of flight) and 50 feet between rows (perpendicular to the flightpath) samples an area 35 feet across and 450 feet long. This sampling array has been used to measure 450-gallon helibucket drops.

The wooden receptacles should be located accurately. A point 240 feet from the flightpath, the centerline of the grid should be located as the station for measuring aircraft height with the Haga altimeter. This permits the

Figure 2.--*Aircraft drop pattern data summary form.*

Pass No. 1

Aircraft height 100

Aircraft speed 45 knots

Type of aircraft HF-1100

Windspeed Calm

Wind direction N/A

Point No.	1	2	3	4	5	6	7
Wt. H_2O + cup	15.4	15.4	15.7	16.1	16.9	16.2	16.0
Wt. cup	15.4	15.2	15.2	15.2	15.1	15.1	15.1
Wt. H_2O	0.0	0.2	0.5	0.9	1.8	1.1	0.9
Gals./100 ft.^{2}	0.0	0.2	0.4	0.7	1.4	0.9	0.7

Point No.	8	9	10	11	12	13	14
Wt. H_2O + cup	15.5	16.9	16.9	17.0	18.0	17.4	16.3
Wt. cup	15.2	15.6	15.2	15.2	15.2	15.1	15.1
Wt. H_2O	0.3	1.3	1.7	1.8	2.8	2.3	1.2
Gals./100 ft.^{2}	0.2	1.0	1.3	1.4	2.1	1.8	0.9

Point No.	15	16	17	18	19	20	21
Wt. H_2O + cup	15.5	17.1	18.0	19.7	17.9	18.3	17.5
Wt. cup	15.1	15.1	15.5	15.3	15.1	15.2	15.2
Wt. H_2O	0.4	2.0	2.5	4.4	2.8	3.1	2.3
Gals./100 ft.^{2}	0.3	1.6	1.9	3.5	2.1	2.4	1.8

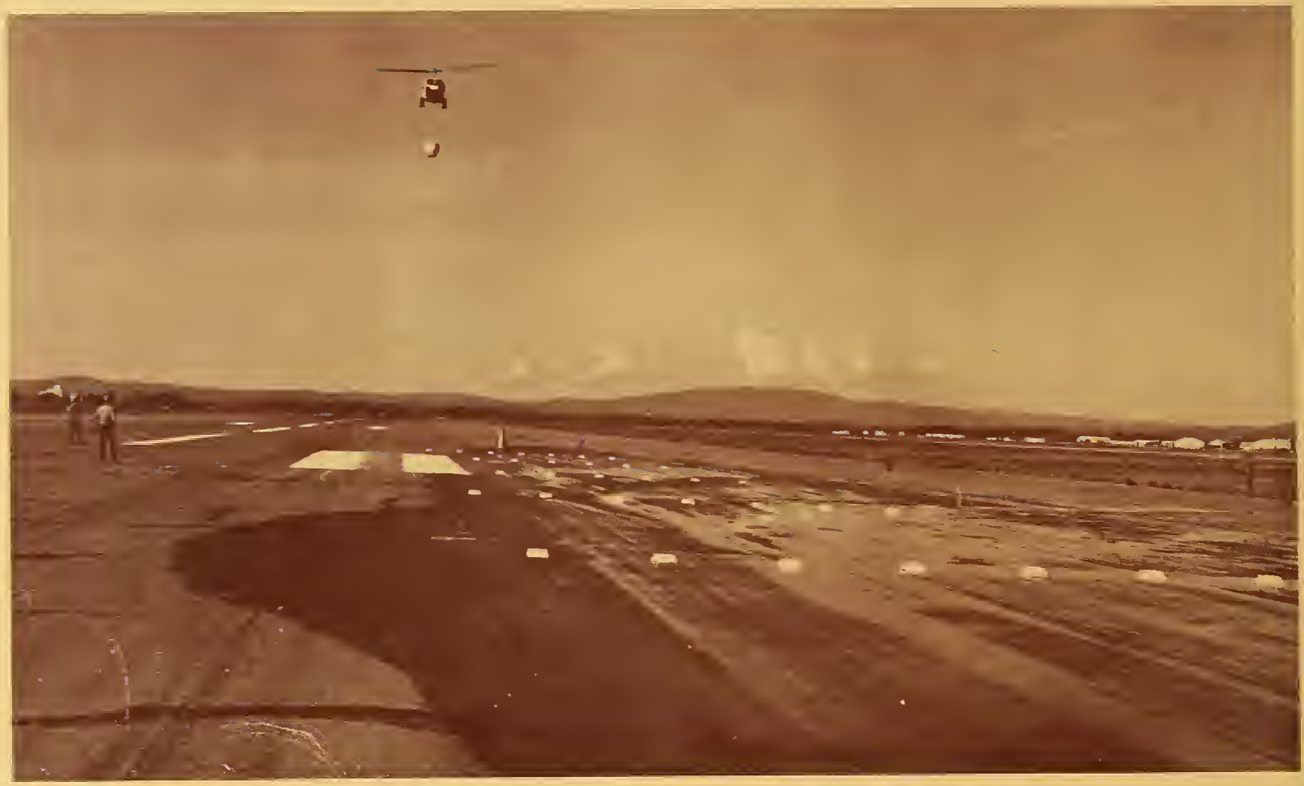

Figure 3.--*The sampling system, including the seven rows and 10 columns of blocks, the location of a man measuring aircraft height, a man measuring windspeed, and one of the two pylons for guiding the aircraft over the area.*

altimeter to be read directly in feet. A point 200 feet from the flightpath provides for reading an Abney level with a percent scale directly in feet. It may be advisable to locate some readily visible colored pylons along the flightpath to aid the pilot in alining and identifying the sampling array.

Conducting the test.-- An important part of the test procedure is assigning specific responsibilities to each crewmember. A briefing with the pilot and a predetermined, mutually agreeable schedule of aircraft altitude, airspeed, etc. should be established. The purpose of the drop test should be discussed with each crewmember so that he thoroughly understands his function. A supervisor and three assistants are a suitable crew.

The supervisor should use the radios to direct the pilot and be responsible for taking notes and recording information for each pass such as aircraft speed, aircraft height, and windspeed and direction (see procedure checklist). One person should be familiar with the Haga altimeter. The second crewmember should be familiar with the use of the wind-measuring device provided in the belt weather kit. The third man describes the general character of the drop or makes other appropriate weather measurements. The three assistants cover the filled sample cups after each pass and remove a second lid in preparation for the next pass. Three men can make this lid change in approximately 5 minutes, which is less time than a helicopter normally requires to hover, fill a helibucket, and return.

The greatest hazard associated with the operation is falling masses of retardant or the accidental release of a helibucket during the pass. A lesser hazard is poor footing after drops of retardant. Personnel should be warned and kept well to the side of the drop zone. Passes should not be made from an aircraft height less than 100 feet over terrain.

Data Reduction

After the passes have been made, receptacles and cups should be collected systematically, loaded, and transported to a sheltered work area with a weighing scale. The outside of each cup should be wiped clean and dry and the covered cup of liquid weighed. The cup should then be emptied, the inside thoroughly cleaned, and the dry cup and lid weighed. The difference between the first weight and the second is the amount of liquid per cup. A conversion factor must be determined for converting the amount of liquid per cup to a standard unit. A standard unit often used is gallons per 100 square feet. Each gram of liquid collected over the area covered by the open cup mouth should be expressed in these units.

An example of how this conversion factor was computed for the 4½-ounce cups described in this article follows:

$$\text{A conversion factor to gallons/100 ft.}^2 = \frac{1 \text{ gram liquid}}{\pi \, (r \text{ inches})^2}$$

$$\times \frac{1}{\text{liquid specific gravity}} \times \frac{144 \text{ inches}^2}{1 \text{ ft.}^2} \times \frac{1 \text{ gallon } (H_2O)}{3,785.43 \text{ grams } (H_2O)} \times 100$$

where:

r = average diameter of several cups divided by 2, and

$\pi = 3.1416$

The weight measurement is in grams per cup-mouth area. The two-step conversion involves (1) expressing a unit (grams or ounces) of the liquid in terms of gallons, and (2) expressing the cup-mouth area in terms of 100-square-foot units.

There are 3,785.43 grams of water per gallon; thus each gram of water equals 1/3,785.43, or 0.000264 gallon.

Cup area is computed by the familiar formula: $A = \pi r^2$. The radius for the 4½-ounce cups is 1.25 inches, or 4.9072 square inches. This is divided by 144 square inches per square foot, converted to 0.034077 square foot, and divided by 100 to yield 0.00034077 100-square-foot unit. The new numerator (0.000264 gallon) is divided by the denominator (0.00034077/100 square feet). Each gram of water collected represents a concentration of 0.775 gallon/100 square feet.

This conversion value (0.775), multiplied by the weight of water in each cup (in grams), gives the concentration at a sample point. The final answer is not accurate to more than the nearest 0.1 of a gallon and should be rounded off. The conversion value (0.775) applies to the 2½-inch diameter plastic cups described. A new conversion value will have to be determined if different size cups are used. The conversion value (0.775) applies to water and must be divided by the specific gravity if retardant is being measured.

Data Summary and Presentation

The information from each pass is then plotted on a graph (fig. 4). The scales of the graph represent distance in feet along the flightpath and distance in feet across the flightpath. The water concentration expressed in gallons per 100 square feet is then entered at each sampling point on the graph paper for the pass. Isolines are drawn through points of equal concentration at appropriate intervals.

Discussion

The maps themselves are very useful descriptions of the ground distribution pattern. They should be subjectively examined for uniformity and other desirable characteristics. Hodgson[2/] has developed criteria for evaluating and summarizing the maximum lengths of contours in feet at the

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[2/] Brian S. Hodgson. A procedure for evaluating ground distribution patterns for water dropping aircraft. For. Fire Res. Inst., Inf. Rep. FS-X-9, 29 p. Ottawa, Ont. 1967.

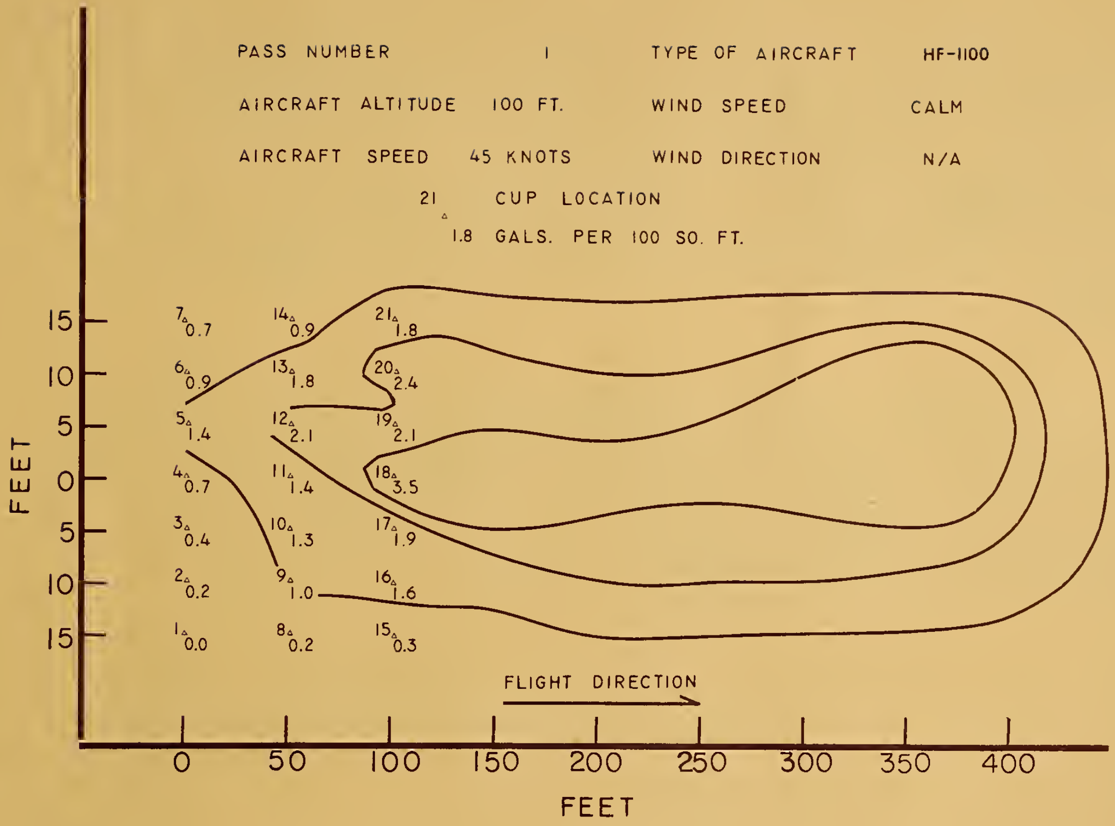

Figure 4.--*Ground distribution pattern showing plotted water concentration information and isolines.*

various concentration levels within drop patterns. Other measures that can be examined are width, area, and portion or drop load accounted for (recovery). Each drop pattern can be considered a sample and hypotheses tested about certain drop pattern parameters. Procedures for establishing a test design to provide a basis for answering questions are readily available.[3] Forestry training in timber cruising provides the background for applying these statistical methods. The technique used for summarizing the data will vary with the purpose of making the drop pattern. However, the technique to be used and the criteria for judging whether the patterns are acceptable should be established during the preplanning period.

The fabrication of cup receptacles, array layout, testing, weighing, and summarizing data can be done by crews on standby. Aircraft flight time costs can be negligible if tests are run during periods when aircraft are not being flown enough to meet minimum contract flight time guarantees. Considerable cost can be justified if an aircraft can be detected that has an undesirable drop pattern that wastes retardant. Cost of materials and special equipment is small. A three-man crew can set up the system, sample nine patterns, and have the field activities completed in less than 4 hours. The biggest time factor is weighing the cups and plotting the patterns.

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[3] Frank Freese. Elementary statistical methods for foresters. U.S. Dep. Agric. Handb. 317, 1967.

Developing a capability to measure ground distribution patterns opens the door to quality control over retardant and water dropping operations. New equipment can be compared with that currently used. Contract aircraft and pilots can be checked and given guidelines for dropping. Field evaluation of aerially applied liquids will be more effective when variation in application rates can be controlled or quantified.

A Procedure Checklist

Predrop

- Define purpose and acceptance criteria
- Purchase cups
- Make cupholders
- Number cups and holders
- Prepare a form
- Purchase or locate a scale (readable to 0.1 gram)
- Assemble equipment:
  - portable tape recorder
  - set of forms
  - belt weather kit
  - cups and lids
  - pylons
  - F.M. radios
  - Haga altimeter
  - 100-foot tape
  - cupholders
- Contact air traffic control and arrange for use of test area
- Establish drop schedule
- Brief crew on safety and assign jobs
- Lay out array

During Drop

- Remove lid from Pass No. 1 cups
- Describe drop on recorder
- Record measured information on form
- Open Pass No. 2 cups and cap Pass No. 1 cups
- Continue

Postdrop

- Systematically collect cupholders with cups
- Weigh cups with water, empty, clean, and reweigh
- Determine weight of water, convert to standard units, plot the data on a graph
- Analyze

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